Design and Development of Special Low Noise Amplifiers for GPS Application

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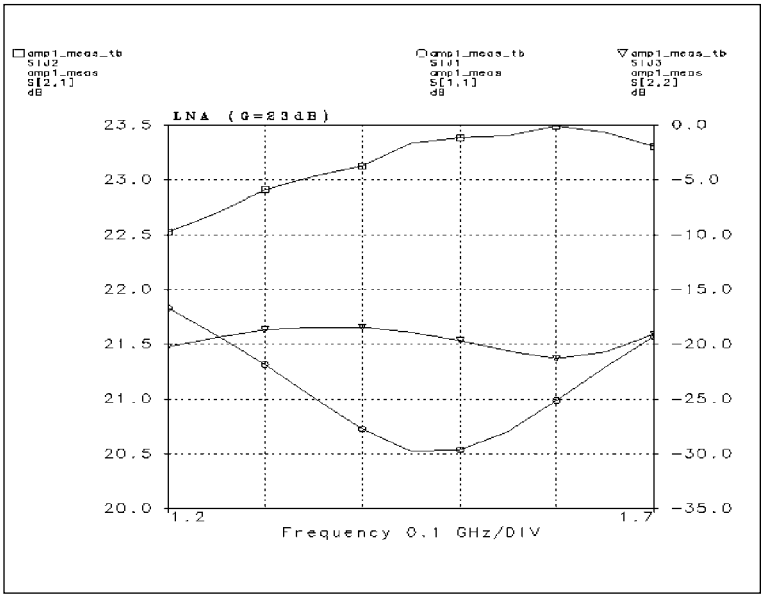
This article describes the design and development of two special low noise amplifiers at the frequency range 1.2 GHz to 1.7 GHz. The gain of these amplifiers is set to 23 dB and 45 dB, and special attention has been given to the thermal compensation of the main characteristics of the LNAs such as gain, noise figure and power consumption.

The amplifiers are designed through the use of commercially available CAD software and a full range of measurements are presented. The special features of these amplifiers include high dynamic range, thermally compensated range over 120° C, very low noise performance and low gain ripple.



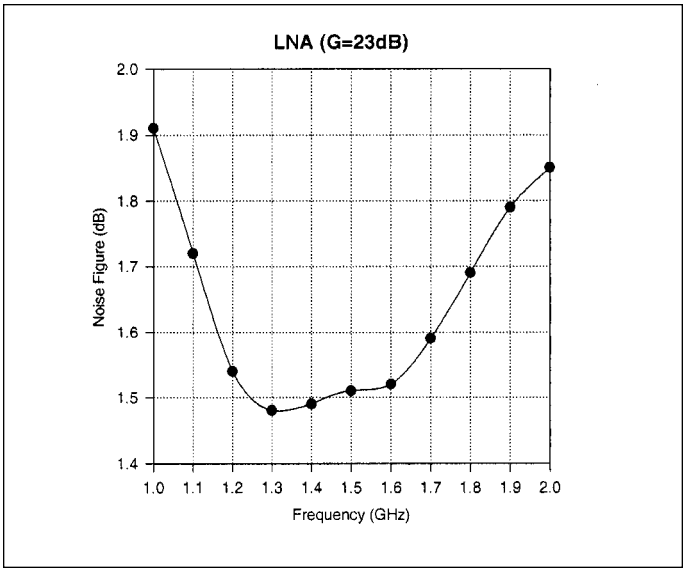
▲ **Figure 1. S-parameter response of LNA 1.**

Introduction

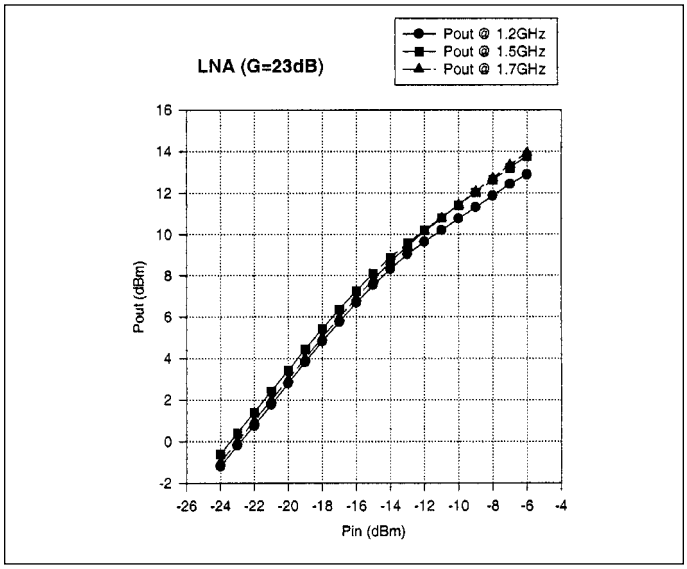
The LNAs are based on the M/A-COM low noise amplifier module MAAM-12000-A1. The target of the project was to produce low cost and high reliability thermally compensated Low Noise Amplifiers. These amplifiers cut at least half the cost off of commercially available amplifiers, and their performance is comparable to similar products. Both are housed in EMI/EMC shielded aluminum boxes with SMA female connectors and feedthrough.

Gain	23 dB±0.5 dB
Frequency Range (GHz)	1.2–1.7
Input Return Loss	<16 dB
Output Return Loss	<18 dB
Noise Figure (max)	1.55 dB
Output 1dB Compression (min)	+10 dBm
Gain variation over temperature (max)	1 dB
Bias Current	100 mA
Bias voltage (stabilized)	+8 Volts
Maximum Input RF power	+20 dBm
Enclosure dimensions	40 × 58 × 10 mm^3
RF connectors	SMA 3.5 mm
EMI/EMC protection	>80 dB
Operating temperature	–40° C to +80° C

▲ **Table 1. Specifications of LNA 1.**



▲ **Figure 2. Noise figure response of the first low noise amplifier design (LNA 1).**



▲ **Figure 3. Output power compression response of LNA 1 at 1 dB.**

Low cost substrate material R4003 from Rogers Corporation has been used for fabrication. Active bias circuitry is used in order to suspend for the gain, power consumption and noise figure variations versus temperature. The temperature range of operation for these amplifiers is –40° C to +80° C. Along with the active bias circuitry, a thermopad attenuator is used in order to additionally compensate for the gain variations versus temperature variations.

The power supply is single positive configuration with an input voltage range of 7 to 28 VDC.

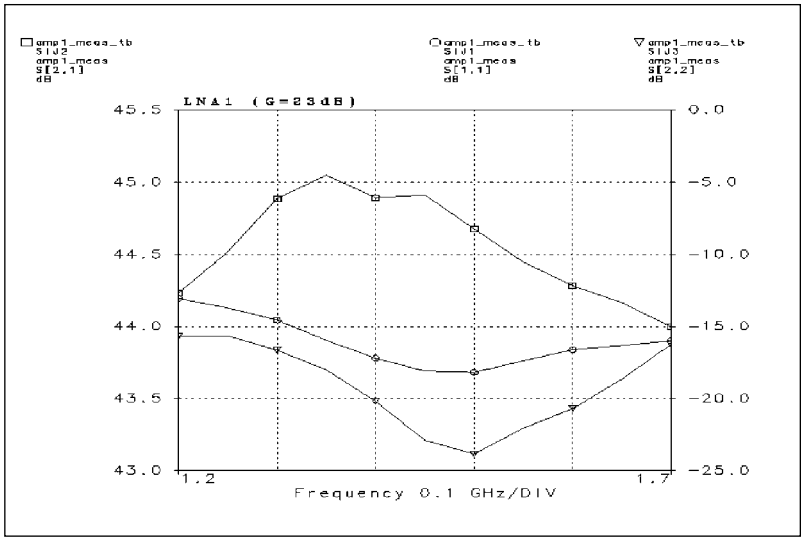
Low noise amplifier 1

The first amplifier is based on a single module MAAM-12000-A1. Based on the CAD simulations, some additional matching is used in order to improve noise figure and return loss as well as gain ripple over the whole frequency range. The specifications of this amplifier are shown in Table 1. The *s*-parameters' response is shown in Figure 1, determined by the VNA HP-8719D. The nominal temperature is 25° C.

The noise figure of the amplifier is measured through the use of the HP-8970B noise figure meter. The response for the nominal temperature is shown in Figure 2. The noise figure is less than 1.55 dB in the frequency range of interest, which is slightly above the minimum noise figure obtainable from the MAAM-12000-A1.

Since this LNA has to have a high dynamic range behavior, the power gain compression at 1 dB is critical. Therefore, swept power measurements are performed using the HP EPM-441A power meter. The output power versus the input power plot is shown in Figure 3.

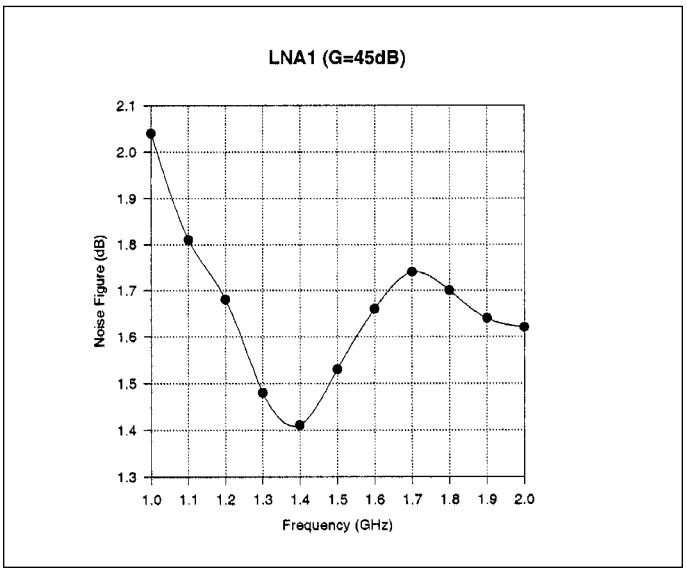
The output power gain compression at 1 dB is at least +10 dBm over the entire frequency range, from 1.2 GHz to 1.7 GHz. From this plot, it is obvious that this amplifier may also be used in environments where unwanted signals have extremely high power levels.



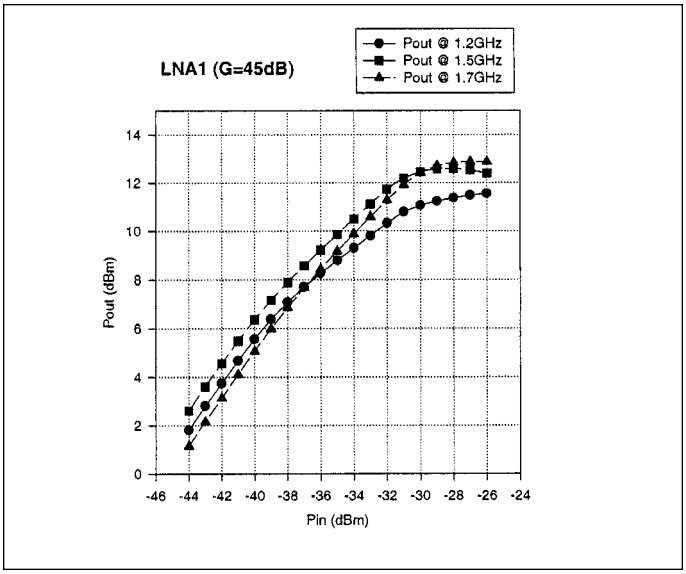
▲ **Figure 4. *S*-parameter response of the second low noise amplifier design (LNA 2).**

Low noise amplifier 2

The second amplifier designed is based on two modules of MAAM-12000-A1. Based on the CAD simulations, some additional matching is used in order to improve noise figure and return losses as well as gain



▲ **Figure 5. Noise figure response of LNA 2.**



▲ **Figure 6. Output power 1 dB compression response of LNA 2.**

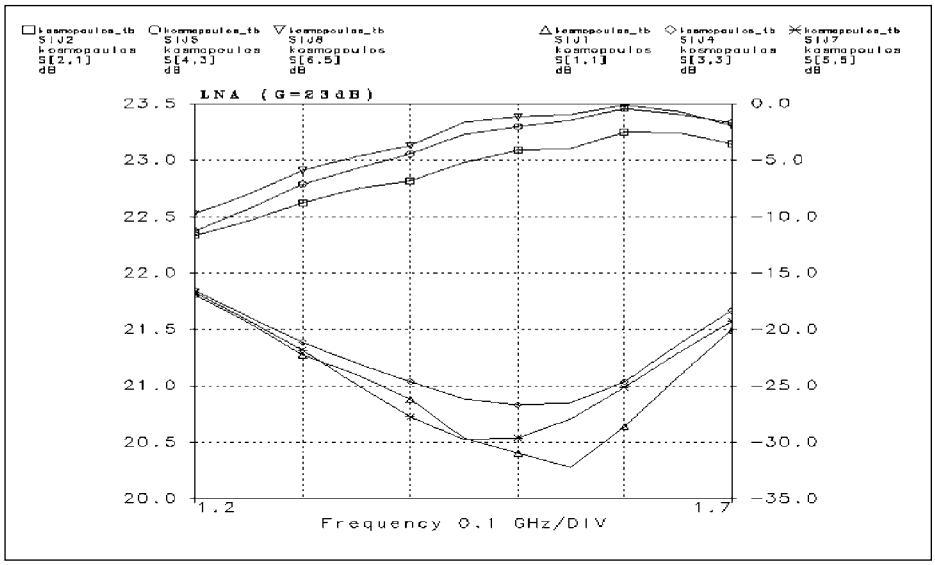
ripple over the entire frequency range. This amplifier has a nominal gain of 45 dB. Due to the large value of gain, care has been taken using electromagnetic CAD software to suppress the slightest possibility of parasitic oscillations. Therefore, two metal strips are placed over the MAAM-12000-A1 modules, as it was advised from the simulation runs. The specifications of this amplifier are shown in Table 2.

The *s*-parameters' response to this amplifier is shown in Figure 4, measured by the VNA HP-8719D. The nominal temperature is 25° C.

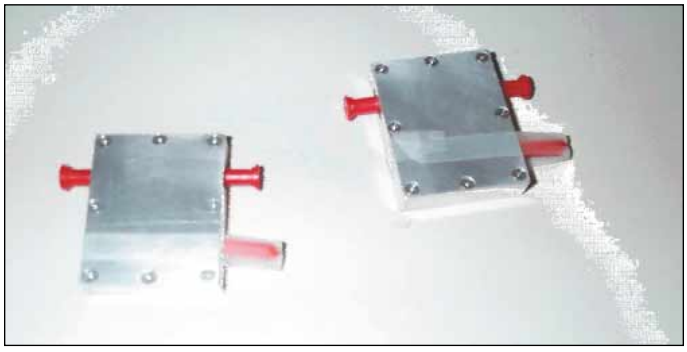
The amplifier's noise figure is measured through the use of the HP-8970B noise figure meter. The response for the nominal temperature is shown in Figure 5. The noise figure is less than 1.75 dB in the frequency range of interest, which is 0.4 dB above the minimum noise figure obtainable from a single MAAM-12000-A1. LNA 2 has a greater noise figure because the gain is quite large and the electromagnetic compensation of possible oscillations is used.

Since this LNA has to have a high dynamic range behavior, the power gain compression at 1 dB is critical. Therefore, swept power measurements are performed using the HP EPM-441A power meter. The output power versus the input power plot is shown in Figure 6.

The output power gain compression at 1 dB is at least +10 dBm over the entire frequency range from 1.2 GHz



▲ **Figure 7. *S*-parameters variation of LNA 1 (triangle = –40° C; circle = +25° C; rectangle = +80° C).**

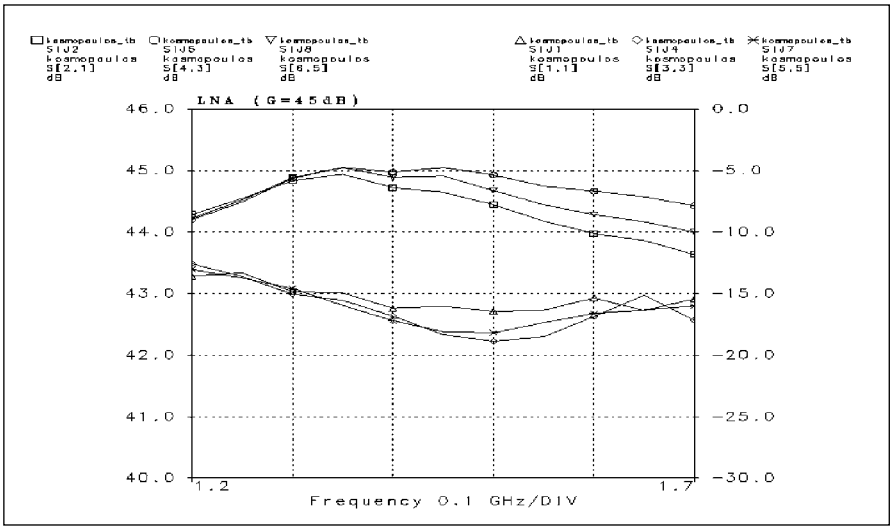


▲ **The LNA 1 and LNA 2 amplifiers.**

to 1.7 GHz. From this plot, it is obvious that this amplifier may also be used in environments where unwanted signals have extremely high power levels.

Along with the above measurements, some measurements versus temperature have been obtained for LNA 1. Figure 7 shows the *s*-parameters' variation versus temperature.

Figure 8 shows the *s*-parameters' variation versus temperature for LNA 2. Figures 7 and 8 show that the total gain variation is less than 1.2 dB over the entire temperature range of 120° C.



▲ **Figure 8. S-parameters variation of LNA2 (triangle = –40° C; circle = +25° C; rectangle = +80° C).**

Conclusions

In this paper, two low noise amplifiers are presented to be used in GPS applications. Both amplifiers have some unique features, including low noise figure; low gain ripple; thermally compensated designs; ultra low return losses; low cost; single positive regulated design using active bias techniques; and selectable gain 23 dB or 45 dB.

A photograph of these two amplifiers is shown on Page 52. The amplifiers are delivered in short time (less than two months) for small quantities after order. Custom specifications can be realized upon request. ■

Gain	44.5 dB ±0.5 dB
Frequency Range (GHz)	1.2 - 1.7
Input Return Loss	<13 dB
Output Return Loss	<16 dB
Noise Figure (max)	1.75 dB
Output 1dB Compression (min)	+10 dBm
Gain variation over temperature (max)	1 dB
Bias Current	200 mA
Bias voltage (stabilized)	+8 Volts
Maximum Input RF power	+20 dBm
Enclosure dimensions	40 × 58 × 10 mm3
RF connectors	SMA 3.5 mm
EMI/EMC protection	>80 dB
Operating temperature	–40° C to +80° C

▲ **Table 2. Specifications of LNA 2.**

Author information

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